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(71) Applicant: **Ajinomoto Co., Inc.**
Tokyo
104-8315 (JP)

(72) Inventors:
• **UEDA, Mitsuo**
Kobe-shi
Hyogo 654-8585 (JP)
• **YOKOYAMA, Keiichi**
Kawasaki-shi
Kanagawa 210-8681 (JP)
• **NIO, Noriki**
Tokyo 104-8315 (JP)

(74) Representative: **Strehl Schübel-Hopf & Partner**
Maximilianstrasse 54
80538 München (DE)

(54) **PROCESSED FIBER PRODUCT, AND METHOD FOR PRODUCTION THEREOF**

(57) A processed fiber product having excellent strength, water-absorbability and washing durability can be produced by attaching a partially hydrolyzed product

of a wheat protein to a fiber and then allowing a trans-glutaminase to act on the fiber.

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Description

Technical Field

5 **[0001]** The present invention relates to a processed fiber product and a method for producing the same using a transglutaminase and a protein or peptide.

Background Art

10 **[0002]** Polyester appeared as the last clothing fiber substrate in the 1950s, and since then no novel significant fiber substrate has been developed. Since the 1950s, insufficient properties of fiber substrates per se have been improved, for example, by modifying a fiber formation procedure such as a spinning procedure or by performing a so-called fiber processing for chemical functionalization. Methods for improving wrinkle resistance of cotton, methods for preventing shrinkage of sheep wool, processings for chemically improving luster or slimy feel of a surface of nylon or polyester, etc.
15 have been widely used.

[0003] So-called enzymatic processings, which use an enzyme for diminishing a defect of a clothing material of a natural fiber target, were developed in the 1990s. Processings using a cellulose-hydrolyzing enzyme for partially hydrolyzing a surface of a cellulose fiber target such as cotton to obtain a good softer texture, and processings using a protein-hydrolyzing enzyme for partially modifying a cuticle surface of a sheep wool target to improve the washing shrinkage of sheep wool, etc. have been studied and partly put into practical use. Also uses of synthetic fiber targets have been spreading in such processings. Though synthetic polymers have been considered unuseful as the substrate, some polymers have been found to be capable of interacting with an enzyme. Thus, attempts to enzymatically modify a surface of a target of nylon, acrylic, polyester, etc. have been performed.

25 **[0004]** The use of the enzymes has been spreading in the fiber processings. However, most of the enzymes for the above processings are hydrolysis enzymes that act only to cut the fiber substrate surface moderately, and thus the application and function thereof are severely limited. Therefore, an enzyme for catalyzing a chemical binding reaction, different from the hydrolysis enzymes, is demanded to add a non-intrinsic function to the fiber substrate.

[0005] Transglutaminase is one of attractive enzymes capable of satisfying the above demand. The transglutaminase acts to bond a glutamine residue and a lysine residue in a protein or to catalyze introduction of a primary amine to a glutamine residue. Thus, the transglutaminase has a high potential to act upon a polyamide-based fiber substrate, thereby actively adding a new function in the fiber processing. In fact, several novel processings using the transglutaminase for a fiber substrate such as sheep wool have already been proposed in the fiber field.

35 **[0006]** The transglutaminase catalyzes the binding reaction between the glutamine and lysine residues, and thus may act upon a fiber substrate having the glutamine and lysine residues or the like. An advantageous effect of the transglutaminase has already been found. For example, when a sheep wool target is practically treated with the transglutaminase, the glutamine and lysine residues in the sheep wool substrate are crosslinked by the enzyme-catalyzed reaction to increase the strength of the sheep wool (Enzyme and Microbial Technology, 34 (2004) p64-72).

[0007] The novel function-added processing utilizing the above advantageous effect cannot be achieved by using the cellulose-or protein-hydrolyzing enzymes, which have been studied for practical use. This processing can be expected to further progress. However, the fiber substrate used in the processing must have both the glutamine and lysine residues, and thereby is limited to some natural fibers such as the sheep wool.

[0008] Polyamide fibers such as silk and nylon other than the sheep wool do not have a sufficient amount of the glutamine and lysine residues or the like interacting with the transglutaminase. Thus, when such a polyamide fiber substrate is directly treated with the transglutaminase, the crosslinking reaction cannot proceed. To accelerate the binding or crosslinking reaction of such a substrate using the transglutaminase, a third component having a large amount of the lacked reactive residue has to be added thereto. For example, a silk fiber substrate contains the lysine and glutamine residues only in small amounts, whereby the residues are not likely to react in the transglutaminase treatment. When the silk is treated with a peptide containing the glutamine and lysine in large amounts beforehand and then subjected to the transglutaminase treatment, the densities of the reactive residues are increased, and the fiber substrate and the third component undergo the binding reaction together, to cause the crosslinking effectively. Furthermore, when various functional substances are added to the additional third component beforehand, the functional substances may be effectively introduced to the fiber substrate in the enzyme-catalyzed reaction.

[0009] Even the synthetic fiber substrate such as nylon is expected that the residue of the synthetic fiber substrate is reacted with the third component by the addition of the third component if the synthetic fiber substrate has a reactive residue serving as a substrate of the transglutaminase, and it may become possible to cause the synthetic fiber substrate crosslinking via the third component or effective introduction of the functional substance as in the case of the silk.

55 **[0010]** Based on this standpoint, JP-A-9-3772 proposes a method containing coating a polyester surface with a gelatin, and discloses that a fiber with high moisture permeability and absorptivity can be obtained by the coating. In this method,

the polyester surface is coated with a high-concentration (30-wt%) aqueous gelatin solution containing the transglutaminase in view of improving the film formability. However, the coating with the high-concentration aqueous gelatin solution is not a practical method because the solution is often converted to the gel state or solidified on a knife coater in the coating process. In addition, in this document, the durability of the resultant coating is evaluated only with respect to dissolution in 90°C hot water, and whether the effect of the coating is maintained in a practical treatment such as washing is not disclosed.

[0011] In view of avoiding the disadvantage of the high-concentration aqueous gelatin solution, JP-A-9-3773 proposes a method in which immersing a polyester is immersed in a 3-wt% aqueous gelatin solution containing the transglutaminase. However, in this document, the durability of the resultant film is evaluated only with respect to dissolution in 90°C hot water, and whether the effect is maintained in a practical treatment such as washing is not disclosed.

[0012] Thus, as is clear from the above methods, the moisture permeability and absorptivity of the fiber can be increased by coating the fiber with the high-concentration gelatin solution. However, it is true that the resultant fiber is poor in wash durability and cannot maintain the water or moisture absorptivity.

Disclosure of the Invention

[0013] Under such circumstances, an object of the present invention is to eliminate the disadvantages of the above related art, thereby providing a method for easily producing a fiber excellent in strength, water absorptivity, and wash durability with low cost.

[0014] As a result of intense research in view of the above object, the inventors have found a method using a partially hydrolyzed wheat protein. The invention has been accomplished based on the finding. Thus, the invention is as follows.

(1) A processed fiber obtained by the steps of attaching a partially hydrolyzed wheat protein to a surface of a fiber and treating the fiber with a transglutaminase.

(2) A processed fiber according to (1), wherein the partially hydrolyzed wheat protein is prepared by treating a wheat protein with an enzyme, an acid, or an alkali.

(3) A processed fiber according to (1) or (2), wherein the partially hydrolyzed wheat protein has an average molecular weight of 700 to 50,000.

(4) A method for producing a processed fiber, characterized by comprising the steps of attaching a partially hydrolyzed wheat protein to a surface of a fiber and treating the fiber with a transglutaminase.

(5) A method according to (4), wherein the partially hydrolyzed wheat protein is prepared by treating a wheat protein with an enzyme, an acid, or an alkali.

(6) A method according to (4) or (5), wherein the partially hydrolyzed wheat protein has an average molecular weight of 700 to 50,000.

[0015] In the invention, the partially hydrolyzed wheat protein means a product obtained by partially hydrolyzing a wheat gluten protein moderately with an enzyme, an acid, an alkali, etc., and does not include non-hydrolyzed wheat proteins and protein hydrolysates obtained by excessively hydrolyzing a protein into amino acids. A commercially available partially enzyme-hydrolyzed wheat gluten protein (such as WGE80GPU available from DMV) may be used as it is. Also it can be prepared by hydrolyzing wheat gluten with an appropriate protein-hydrolyzing enzyme. Alternatively, the partially hydrolyzed wheat protein may be a partially acid- or alkali-hydrolyzed wheat gluten protein. The average molecular weight of the partially hydrolyzed wheat protein is preferably 700 to 50,000 Da, more preferably 3,000 to 40,000 Da and particularly preferably 5,000 to 30,000 Da.

[0016] There are no particular limitations on the method for attaching the partially hydrolyzed wheat protein to the fiber surface. For example, the partially hydrolyzed wheat protein may be attached to the fiber by immersing the fiber in a solution prepared by dissolving or dispersing the partially hydrolyzed wheat protein in a solvent such as water, or by coating or spraying the partially hydrolyzed wheat protein onto the fiber. The partially hydrolyzed wheat protein may be present in at least a gap or surface of a monofilament or staple in a thread of the fiber, and may adhere to or cover the monofilament or staple.

[0017] The concentration of the partially hydrolyzed wheat protein solution, used for immersing the fiber in the solution prepared by dissolving or dispersing the partially hydrolyzed wheat protein in the solvent such as water or for coating or spraying the partially hydrolyzed wheat protein onto the fiber, is preferably 1 to 30 g/L. The concentration is more preferably 3 to 10 g/L from the viewpoints of cost and workability.

[0018] The amount of the partially hydrolyzed wheat protein attached to the fiber surface is preferably 0.1 to 3 g per 1 g of the fiber. The amount is more preferably 0.3 to 1 g from the viewpoints of cost and workability.

[0019] The transglutaminase (which may be hereinafter referred to as TG) used in the invention is an acyltransferase of EC 2.3.2.13, and has an activity for catalyzing an acyl transfer reaction between a glutamine residue donor and a lysine residue acceptor in the protein or peptide. Known transglutaminases are derived from various sources such as

mammals, fishes, and microorganisms. The transglutaminase used in the invention may be any enzyme as long as it has the above activity, may be derived from any source, and may be a recombinant enzyme. Examples of the transglutaminases include those derived from microorganisms such as actinomycetes (see Japanese Patent No. 2572716) and bacillus subtilis (see Japanese Patent No. 3873408). The examples further include those derived from guinea pig livers (see Japanese Patent No. 1689614), those derived from microorganisms (see WO 96/06931), those derived from animals such as bovine bloods and pig bloods, those derived from fishes such as salmon and red sea breams (Seki, et al., Nippon Suisan Gakkaishi, 1990, 56, 125-132), and those derived from oysters (see United States Patent No. 5736356). In addition, the examples further include those produced by genetic recombination (see, for example, Japanese Patent No. 3010589, JP-A-11-75876, WO 01/23591, WO 02/081694, and WO 2004/078973), and disulfide bond-introduced transglutaminases with improved heat resistance (WO 2008/099898).

[0020] A commercially available transglutaminase derived from a microorganism under the product name of "ACTIVA" TG from Ajinomoto Co., Inc. is an example which may be used in the invention.

[0021] Examples of methods to allow TG to act include a method to immerse the fiber in a solution containing the partially hydrolyzed wheat protein and the TG, or and a method to immerse the fiber in the partially hydrolyzed wheat protein solution followed by immersing it in a TG solution. The pH of the solution containing the partially hydrolyzed wheat protein and the TG or the TG solution is preferably 4 to 12, more preferably 5 to 8, from the viewpoints of the enzymatic reactivity and stability of the TG.

[0022] The enzymatic reaction time is not particularly limited as long as the enzyme can sufficiently act upon the substrate in the time. Though the fiber may be treated with the enzyme for a remarkably short time or a long time, the reaction time is preferably 5 minutes to 24 hours practically. Also the reaction temperature is not particularly limited as long as the enzyme can maintain the activity. The reaction temperature is preferably 0°C to 80°C practically.

[0023] The optimum addition amount of the TG, as the TG concentration of the solution containing the partially hydrolyzed wheat protein and the TG or the TG solution, is 10 to 3,000 U/L, preferably 100 to 3,000 U/L, more preferably 1,000 to 3,000 U/L. The TG concentration may be appropriately controlled depending on the type of the fiber, the TG reaction time, the TG reaction temperature, etc. When the TG concentration is more than 3,000 U/L, the effect of the TG can be achieved but is inadequate to compensate for the cost.

[0024] The addition amount of the TG is preferably 1 to 300 U per 1 g of the fiber, and is preferably 1 to 300 U per 1 g of the partially hydrolyzed wheat protein. The TG amount may be appropriately controlled depending on the type of the fiber, the TG reaction temperature, etc.

[0025] The enzymatic activity is calculated as follows. The enzyme is used in a reaction between substrates of benzoyloxycarbonyl-L-glutamylglycine and hydroxylamine, thus generated hydroxamic acid is converted to an iron complex in the presence of trichloroacetic acid, the absorbance of the resultant is measured at 525 nm, and the amount of the hydroxamic acid is obtained using a calibration curve to calculate the activity. 1 U is defined as the amount of the enzyme that generates 1 μ mol of the hydroxamic acid in 1 minute at 37°C at a pH of 6.0.

[0026] The processed fiber of the invention is a substance produced from a natural fiber such as sheep wool, silk, or cotton, a synthetic fiber such as nylon, polyester, or acrylic, or a blended, mix-twisted, or combined fiber thereof. In the case of using a protein-based fiber (such as sheep wool or silk) or a polyamide-based fiber (such as nylon), the adhesion between the fiber and the protein is further improved because the terminal amino group contributes to the crosslink bonds by the transglutaminase reaction.

Best Mode for Carrying Out the Invention

[0027] The present invention will be described in more detail below with reference to Examples. The invention is not limited to Examples.

Example 1

[0028] The following proteins and enzyme were used in Examples.
Protein

Glutamine peptide A: a partially hydrolyzed wheat gluten protein WGE80GPU available from DMV (average molecular weight 9,650 D)

Glutamine peptide B: a partially hydrolyzed wheat gluten protein B: WGE80GPA available from DMV (average molecular weight 660 D)

Gelatin A: a bovine-derived alkali-treated gelatin available from Kishida Chemical Co., Ltd.

Enzyme

Transglutaminase (EC 2.3.2.13)

Enzyme source: derived from an actinomycete *Streptomyces mobaraensis*

Enzymatic activity: 1,000 U/g

[0029] Approximately 1 g of a silk fabric (Standard adjacent fabric No. 2-1 of a plain *habutae* silk according to JIS L 0803) was subjected to an exhaustion treatment at 40°C for 1 hour in 100 ml of an aqueous solution containing the glutamine peptide (A or B; 2 types) or the gelatin A in the same amount (1 g). After the exhaustion treatment using the glutamine peptide or gelatin, the silk fabric was dried, subjected to an enzyme treatment at 40°C for 1 hour in 100 ml of a Tris-HCl buffer solution (pH 7) containing 10 mg (100 U/L) of the transglutaminase, and then dried. (Also a silk fabric, which was not subjected to the protein exhaustion treatment, was treated with the TG as a control.)

[0030] The tear strength of the processed silk fabric was measured in Newton N in the warp cutting direction by Pendulum method according to JIS L 1096. Furthermore, the processed silk fabric was washed three times with 1 L of distilled water at 40°C for 10 minutes while stirring with a stirrer, to evaluate the influence of the repeated water washing on the strength of the fabric. Then, the fabric was dried, and the tear strength was measured in the same manner as above.

[0031] As shown in Table 1, all the processed silk fabrics, exhaustion-treated with the glutamine peptide A or B or the gelatin A, exhibited increased silk fiber strengths. Particularly the glutamine peptide A-treated fabric maintained the strength even after the washing, and exhibited the largest strength increase. It is clear from the results that the glutamine peptide A was firmly attached to the silk fabric surface by the transglutaminase reaction. In contrast, the gelatin-treated fabric did not have a sufficient tear strength. Thus, the method of the invention using the partially hydrolyzed wheat protein had more significant advantageous effects as compared with the method disclosed in JP-A-9-3773.

Table 1. Strength of silk fiber treated with various proteins

Protein		Glutamine peptide A	Glutamine peptide B	Gelatin A	None	None
TG treatment		Treated	Treated	Treated	Treated	Not treated
Tear strength (N)	After treatment	7.3	5.1	4.9	4.5	3.8
	After washing	7.4	5.2	5.0	4.4	Not determined

Example 2

[0032] The following proteins, different from the proteins used in Example 1, were used in the experiment to evaluate the influences of the type and molecular weight of protein.

Protein

Glutamine peptide C: a partially hydrolyzed wheat gluten

protein SWP500 available from Amylum (molecular weight 5,000 to 30,000 D, estimated from SDS-PAGE)

Glutamine peptide D: a self-prepared partially hydrolyzed wheat gluten protein (average molecular weight 3,000 D)

Glutamine peptide E: a partially hydrolyzed wheat gluten protein GLUPAL 30 available from Katayama Chemical, Inc. (hydrolyzed by acid and alkali, molecular weight 40,000 to 50,000 D)

[0033] The glutamine peptide D was prepared by partially hydrolyzing a wheat gluten with a protease (a *Bacillus amyloliquefaciens* MRP protein) to an average molecular weight of 3,000 D. After the hydrolysis, insoluble components were removed, and the resultant peptide was spray-dried into the powder form.

[0034] Approximately 1 g of a silk fabric (Standard adjacent fabric No. 2-1 of a plain *habutae* silk according to JIS L 0803) was subjected to an exhaustion treatment at 40°C for 1 hour in 100 ml of an aqueous solution containing one of the three glutamine peptides in the same amount (1 g). After the glutamine peptide exhaustion treatment, the silk fabric was dried, subjected to an enzyme treatment at 40°C for 1 hour in 400 ml of a Tris-HCl buffer solution (pH 7) containing 40 mg (100 U/L) of the transglutaminase, and then dried. The tear strength of the processed silk fabric was measured in Newton N in the warp cutting direction by Pendulum method according to JIS L 1096.

[0035] The results are shown in Table 2 together with the results of Example 1. The tear strength of the glutamine peptide-treated fabric was improved with the increase of the average molecular weight. Particularly the glutamine peptide C-treated fabric had a smooth texture. Also the glutamine peptide E-treated fabric exhibited an increased tear strength even though hydrolyzed with acid and alkali.

Table 2. Influence of protein molecular weight on silk fiber strength

Protein	Glutamine peptide B	Glutamine peptide D	Glutamine peptide A	Glutamine peptide C	Glutamine peptide E	Not treated
Average molecular weight (D)	660	3,000	10,000	5,000 to 30,000	40,000 to 50,000	-
Tear strength (N)	5.1	6.9	7.3	11.2	8.7	3.8

Example 3

[0036] The glutamine peptide C described in Example 2 was used in the following experiment to evaluate the influences of the concentrations of the protein and transglutaminase.

[0037] Approximately 1 g of a silk fabric (Standard adjacent fabric No. 2-1 of a plain *habutae* silk according to JIS L 0803) was subjected to an exhaustion treatment at 40°C for 1 hour in 100 ml of an aqueous solution containing the glutamine peptide C. After the glutamine peptide C exhaustion treatment, the silk fabric was dried, subjected to an enzyme treatment at 40°C for 1 hour in 100 ml of a Tris-HCl buffer solution (pH 7) containing the transglutaminase, and then dried. The concentrations of the protein and transglutaminase used in the treatments are shown in Table 3. The tear strength of the processed silk fabric was measured in Newton N in the warp cutting direction by Pendulum method according to JIS L 1096.

[0038] The results are shown in Table 3. A significant effect was achieved at a protein concentration of 1 g/L or more, and the tear strength of the processed fabric was greatly improved with the increase of the concentration. The tear strength was greatly improved under all the examined transglutaminase concentrations.

Table 3. Influence of protein concentration and transglutaminase concentration on silk fiber strength

Protein concentration (g/L)	0.1	0.3	1	3	10	30
Enzymatic activity (U/L)	1,000	1,000	1,000	1,000	1,000	1,000
Tear strength (N)	4.67	4.55	6.08	8.88	11.46	12.91
Protein concentration (g/L)	10	10	10	10	0	0
Enzymatic activity (U/L)	10	30	100	3,000	3,000	0
Tear strength (N)	12.39	10.56	11.39	11.90	4.33	4.10

Example 4

[0039] 1 g of a polyester fabric (Standard adjacent fabric of a polyester according to JIS L 0803) was subjected to an exhaustion treatment at 40°C for 1 hour in 100 ml of an aqueous solution containing the glutamine peptide A or the gelatin A in the same amount (1 g). After the exhaustion treatment using the glutamine peptide A or gelatin A, the polyester fabric was dried, subjected to a TG treatment at 40°C for 1 hour in 100 ml of a Tris-HCl buffer solution (pH 7) containing 10 mg (100 U/L) of the transglutaminase, and then dried. (Also a polyester fabric, which was not subjected to the protein exhaustion treatment, was treated with the enzyme as a control.)

[0040] The tear strength of the processed polyester fabric was measured in Newton N in the warp cutting direction by Pendulum method according to JIS L 1096. The processed polyester fabric was subjected to a water absorbency test using a dropping method according to JIS L 1907 to evaluate the change of the surface hydrophilicity of the fabric. In this dropping method, the water droplet infiltration area was measured in cm² 1-minute after dropping water. Furthermore, the processed polyester fabric was subjected to a repeated washing test under conditions of A-2 method according to JIS L 0844 (40°C, 5-g/L detergent, stirred at 42 rpm, 30 minutes) to evaluate the influence of the repeated washing on the surface hydrophilicity of the fabric. The detergent was used in the first washing and not used in the second washing. The washed fabric was dried, and then the surface hydrophilicity was measured in the above manner.

[0041] As shown in Table 4, the processed polyester fabric, exhaustion-treated with the glutamine peptide A, exhibited an increased tear strength. The processed polyester fabrics, exhaustion-treated with the glutamine peptide A or the gelatin A, had greatly increased surface hydrophilicities. However, only the glutamine peptide-treated fabric maintained

the surface hydrophilicity even after the washing test. It was confirmed that when the glutamine peptide A was attached to the polyester surface and the polyester fabric was treated with the TG, the resultant processed polyester fabric had the increased surface hydrophilicity even after the washing. The polyester is disadvantageous only in that it cannot absorb water (perspiration), and therefore is often blended with a cotton to diminish the disadvantage. It is suggested that the surface water infiltration of the polyester can be improved by the method of the invention to improve the disadvantage.

[0042] In contrast, the gelatin-treated polyester fabric did not have sufficient tear strength and water droplet infiltration area. Thus, the method of the invention using the partially hydrolyzed wheat protein had more significant advantageous effects as compared with the method disclosed in JP-A-9-3773.

Table 4. Strength and water droplet infiltration area of polyester treated with various proteins

Protein		Glutamine peptide A	Gelatin A	None	None
TG treatment		Treated	Treated	Treated	Not treated
Tear strength (N)	After treatment	10.6	8.7	9.0	8.5
Water droplet infiltration area (cm ²)	After treatment	3.02	1.82	1.35	0.19
	After washing	2.89	0.34	0.48	0.37

Example 5

[0043] 1 g of a nylon fabric (Standard adjacent fabric of a nylon according to JIS L 0803) was subjected to an exhaustion treatment at 40°C for 1 hour in 100 ml of an aqueous solution containing the glutamine peptide A or the gelatin A in the same amount (1 g). After the exhaustion treatment using the glutamine peptide A or gelatin A, the nylon fabric was dried, subjected to a TG treatment at 40°C for 1 hour in 100 ml of a Tris-HCl buffer solution (pH 7) containing 10 mg (100 U/L) of the transglutaminase, and then dried. Also a nylon fabric, which was not subjected to the protein exhaustion treatment, was treated with the enzyme as a control.

[0044] The tear strength of the processed nylon fabric was measured in Newton N in the warp cutting direction by Pendulum method according to JIS L 1096. The processed nylon fabric was subjected to a water absorbency test using a dropping method according to JIS L 1907 to evaluate the change of the surface hydrophilicity of the fabric. In this dropping method, the water droplet infiltration area was measured in cm² 1-minute after dropping water. Furthermore, the processed nylon fabric was subjected to a repeated washing test under conditions of A-2 method according to JIS L 0844 (40°C, 5-g/L detergent, stirred at 42 rpm, 30 minutes) to evaluate the influence of the repeated washing on the surface hydrophilicity of the fabric. The detergent was used in the first washing and not used in the second washing. The washed fabric was dried, and then the surface hydrophilicity was measured in the above manner.

[0045] As shown in Table 5, the processed nylon fabrics, exhaustion-treated with the glutamine peptide A or the gelatin A, exhibited increased tear strengths. The processed polyester fabrics, exhaustion-treated with the glutamine peptide A or the gelatin A, had increased surface hydrophilicities. The water droplet infiltration area of the glutamine peptide A-treated fabric was four or more times as large as that of the gelatin A-treated fabric. Furthermore, only the glutamine peptide-treated fabric maintained the surface hydrophilicity even after the washing test. It was confirmed that when the glutamine peptide A was attached to the nylon surface and the nylon fabric was treated with the TG, the resultant processed nylon fabric had the increased surface hydrophilicity even after the washing. In contrast, the gelatin-treated nylon fabric did not have a sufficient water droplet infiltration area. Thus, the method of the invention using the partially hydrolyzed wheat protein had more significant advantageous effects as compared with the method disclosed in JP-A-9-3773.

Table 5. Strength and water droplet infiltration area of nylon treated with various proteins

Protein		Glutamine peptide A	Gelatin A	None	None
TG treatment		Treated	Treated	Treated	Not treated
Tear strength (N)	After treatment	28.1	27.2	24.6	22.7
Water droplet infiltration area (cm ²)	After treatment	4.58	1.00	0.18	0.37
	After washing	1.77	0.31	0.27	0.16

Example 6

[0046] 1.25 g of a polyester fabric (Standard adjacent fabric of a polyester according to JIS L 0803) was subjected to an exhaustion treatment at 40°C for 1 hour in 200 ml of an aqueous solution containing the glutamine peptide A in the same amount (1.25 g). After the peptide exhaustion treatment, the polyester fabric was dried, subjected to a TG treatment at 40°C for 1 hour in 200 ml of a Tris-HCl buffer solution (pH 7) containing 200 mg (1,000 U/L) of the transglutaminase, and then dried. (Also a polyester fabric, which was not subjected to the protein exhaustion treatment and the enzyme treatment, and a polyester fabric, which was subjected only to the protein exhaustion treatment, were prepared as controls.)

[0047] The processed polyester fabric was subjected to a repeated washing test under conditions of A-2 method according to JIS L 0844 (40°C, 5-g/L detergent, stirred at 42 rpm, 30 minutes). In each washing, the fabric was washed using the detergent, washed without the detergent, and then naturally dried. A water absorbency test using a dropping method according to JIS L 1907 was carried out before the repeated washing, after the first washing, after the fifth washing, and after the tenth washing. In this dropping method, the water droplet infiltration area was measured in cm² 1-minute after dropping water.

[0048] The results are shown in Table 6. The processed polyester fabric, treated only with the glutamine peptide A and not treated with the transglutaminase, exhibited no effects after the fifth washing. In contrast, the processed polyester fabric, treated with both the glutamine peptide A and the transglutaminase, maintained the advantageous effects even after the tenth washing.

Table 6. Influence of washing number on water droplet surface area of TG-treated polyester

Water droplet infiltration area (cm ²)	Before washing	After first washing	After fifth washing	After tenth washing
-	0.94	0.94	0.94	0.94
Glutamine peptide A	8.75	2.81	0.94	0.94
Glutamine peptide A + TG	9.06	5.31	4.69	3.75

Example 7

[0049] The glutamine peptide A was used in the following experiment to evaluate the influences of the concentrations of the protein and transglutaminase.

[0050] 1.25 g of a polyester fabric (Standard adjacent fabric of a polyester according to JIS L 0803) was subjected to an exhaustion treatment at 40°C for 1 hour in 200 ml of an aqueous solution containing the glutamine peptide A in the same amount (1.25 g) or one-tenth thereof (0.125 g). After the peptide exhaustion treatment, the polyester fabric was dried, subjected to a TG treatment at 40°C for 1 hour in 200 ml of a Tris-HCl buffer solution (pH 7) containing 2,000 or 200 mg (10,000 or 1,000 U/L) of the transglutaminase, and then dried.

(Also a polyester fabric, which was subjected only to the protein exhaustion treatment without the enzyme treatment, was prepared as a control.)

[0051] The processed polyester fabric was subjected to a repeated washing test under conditions of A-2 method according to JIS L 0844 (40°C, 5-g/L detergent, stirred at 42 rpm, 30 minutes). In each washing, the fabric was washed using the detergent, washed without the detergent, and then naturally dried. A water absorbency test using a dropping method according to JIS L 1907 was carried out before the repeated washing, after the first washing, after the fifth washing, and after the tenth washing. In this dropping method, the water droplet infiltration area was measured in cm² 1-minute after dropping water.

[0052] The results are shown in Table 7. The processed polyester fabrics produced using the ten-fold enzyme concentration or the one-tenth peptide concentration maintained the advantageous effects even after the tenth washing.

Table 7. Influence of washing number on water droplet surface area of TG-treated polyester

Water droplet infiltration area (cm ²)	Before washing	After first washing	After fifth washing	After tenth washing
Glutamine peptide A (6.25 g/L)	6.90	0.90	0.90	0.90
Glutamine peptide A (6.25 g/L) + TG (10,000 U/L)	6.90	6.90	4.70	4.70

(continued)

Water droplet infiltration area (cm ²)	Before washing	After first washing	After fifth washing	After tenth washing
Water droplet infiltration area (cm ²)	Before washing	After first washing	After fifth washing	After tenth washing
Glutamine peptide A (0.625 g/L)	9.10	0.90	0.90	0.90
Glutamine peptide A (0.625 g/L) + TG (10,000 U/L)	9.10	4.70	4.70	2.10

Example 8

[0053] 1.25 g of a polyester fabric (Standard adjacent fabric of a polyester according to JIS L 0803) was subjected to a glutamine peptide exhaustion treatment and a transglutaminase treatment simultaneously at 40°C for 1 hour in 100 ml of a Tris-HCl buffer solution (pH 7) containing the same amount (1.25 g) of the glutamine peptide A and 1,000 mg (10,000 U/L) of the transglutaminase.

[0054] The processed polyester fabric was subjected to a repeated washing test under conditions of A-2 method according to JIS L 0844 (40°C, 5-g/L detergent, stirred at 42 rpm, 30 minutes). In each washing, the fabric was washed using the detergent, washed without the detergent, and then naturally dried. A water absorbency test using a dropping method according to JIS L 1907 was carried out before the repeated washing, after the first washing, after the fifth washing, and after the tenth washing. In this dropping method, the water droplet infiltration area was measured in cm² 1-minute after dropping water.

[0055] The results are shown in Table 8. Even when the glutamine peptide A exhaustion treatment and the transglutaminase treatment were carried out at the same time, the resultant processed polyester fabric maintained the advantageous effects even after the tenth washing.

Table 8

Water droplet infiltration area (cm ²)	Before washing	After first washing	After fifth washing	After tenth washing
Glutamine peptide A + TG	12.50	6.25	4.40	2.10

Industrial Applicability

[0056] In the present invention, the processed fiber having increased strength and excellent water absorbency can be easily produced with low cost. Thus, the invention is extremely useful in the textile industrial field.

Claims

1. A processed fiber obtained by the steps of attaching a partially hydrolyzed wheat protein to a surface of a fiber and treating the fiber with a transglutaminase.
2. A processed fiber according to claim 1, wherein the partially hydrolyzed wheat protein is prepared by treating a wheat protein with an enzyme, an acid, or an alkali.
3. A processed fiber according to claim 1 or 2, wherein the partially hydrolyzed wheat protein has an average molecular weight of 700 to 50,000.
4. A method for producing a processed fiber, **characterized by** comprising the steps of attaching a partially hydrolyzed wheat protein to a surface of a fiber and treating the fiber with a transglutaminase.
5. A method according to claim 4, wherein the partially hydrolyzed wheat protein is prepared by treating a wheat protein with an enzyme, an acid, or an alkali.

6. A method according to claim 4 or 5, wherein the partially hydrolyzed wheat protein has an average molecular weight of 700 to 50,000.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2008/071282

A. CLASSIFICATION OF SUBJECT MATTER

D06M16/00 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

D06M16/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2008
Kokai Jitsuyo Shinan Koho	1971-2008	Toroku Jitsuyo Shinan Koho	1994-2008

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 9-3772 A (Toray Industries, Inc.), 07 January, 1997 (07.01.97), Claim 4; Par. No. [0023] (Family: none)	1-6
Y	JP 10-53964 A (Toray Industries, Inc.), 24 February, 1998 (24.02.98), Par. No. [0019] (Family: none)	1-6

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

Date of the actual completion of the international search
03 December, 2008 (03.12.08)Date of mailing of the international search report
16 December, 2008 (16.12.08)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

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REFERENCES CITED IN THE DESCRIPTION

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